6. DATA PROCESSING

Data processing consisted of ordering the data and placing the results in an ASCII file for plotting. Since the distance between a specific transmitter and the receiver does not necessarily monotonically increase or decrease with each successive data point, the data were processed by ordering the data according to distance. This was performed for each of the five different routes. After ordering the data, three parameters were written to an ASCII file: distance, DGPS field strength, and noise field strength.

7. ANALYSIS

Results showing the signal strength as a function of distance from the transmitter for each of the five different routes are shown in Figures 3 through 7. The signal strength and noise as seen at the input to the antenna are plotted against the distance on the abscissa. The linear regression for signal strength as a function of the log base 10 of the distance was also determined for the first 100 km on each of the routes except the route to Medford, Oregon. Table 2 lists the field strength at 10 km and the slope for the different regression plots. These linear regressions are based on averages as opposed to the best possible signal strength that can be received at a specified distance. Therefore, the field strength at 10 km for the linear regression will show values less than those determined through theoretical predictions.

8. MEASUREMENT RESULTS

For each of the plots except the route to Medford, Oregon, there appears to be a bimodal distribution of points for the first 45 km. This is believed to be due to a difference in terrain between two approaches to and from the transmitter, one approach traveling 45 km west of the transmitter along Interstate 84, and the other approach traveling east of the transmitter along the same highway. For all routes except the one to Medford, Oregon, the data were collected starting on one side of the transmitter, passing it, and proceeding in the opposite side. On the first day, the data collection started east of the transmitter and ended at Cascade Locks, 46 km west of the Appleton site. All other routes started at Cascade Locks, three of which went past the GWEN site traveling east. Separation of the data for the two approaches shows greater signal power for routes traveling to the east of the transmitter. Figure 8 shows the three-dimensional topography of the of the two approaches (Interstate 84 highlighted in yellow).[2] One can see that the land west of the GWEN site at Appleton, Washington is characterized by rough terrain surrounding the gorge of the Columbia River. Figure 9 shows the terrain profile from the transmitter to Cascade Locks, Oregon. Figure 10 shows the terrain profile from the transmitter to Interstate 84, 45 km to the east. The land to the east is flatter except for a narrow gorge and a ridge along the north side of the river. It is interesting to

---

[2] Digital elevation maps, terrain profile plots, and three-dimensional topographical maps were generated through the Telecommunications Analysis Service at ITS.
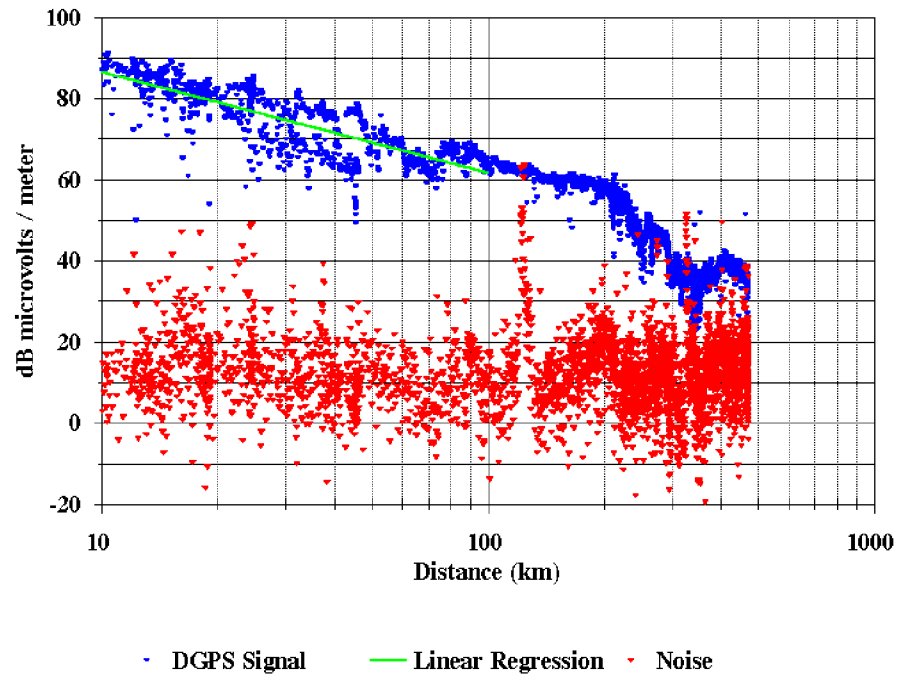
Figure 3.   Signal strength vs. distance for the Appleton GWEN site coming from Boise, Idaho via Interstate 84.
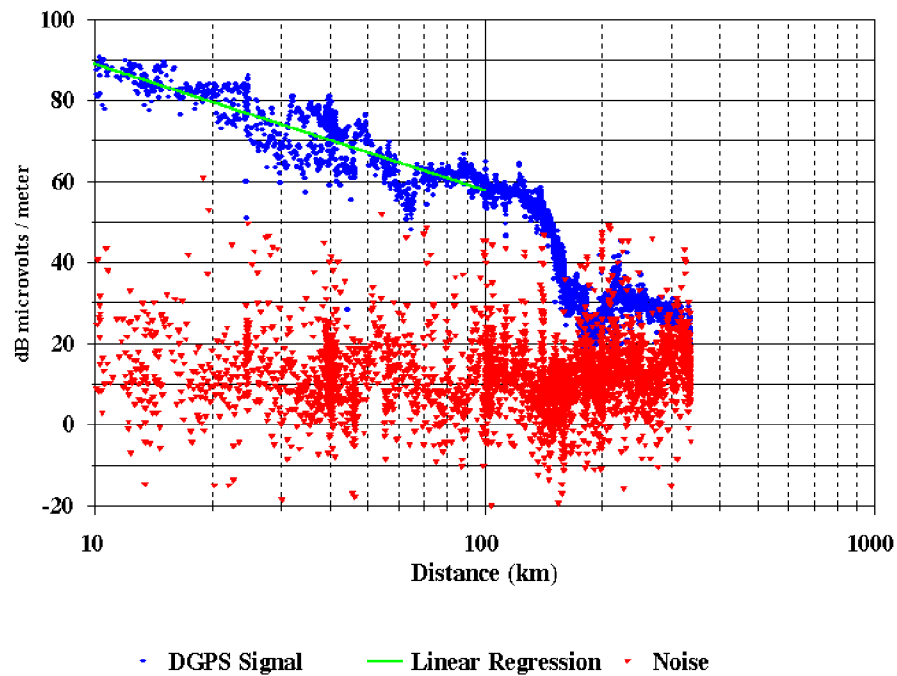

Figure 4.   Signal strength vs. distance for the Appleton GWEN site going to Bellingham, Washington via Highways 97 and 5.
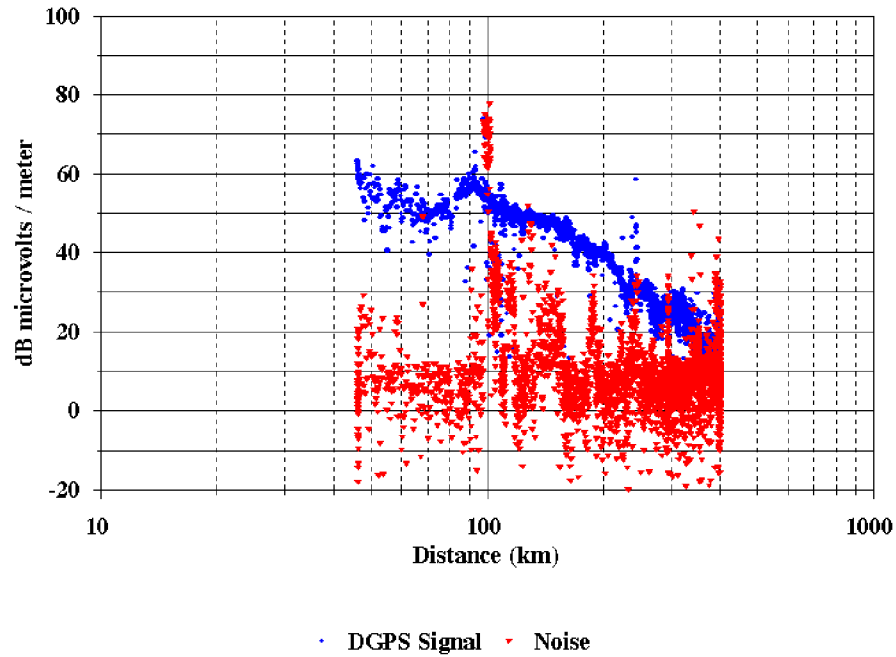
7

Figure 5. **Signal strength vs. distance for the Appleton GWEN site going to Medford, Oregon via Interstate 5.**
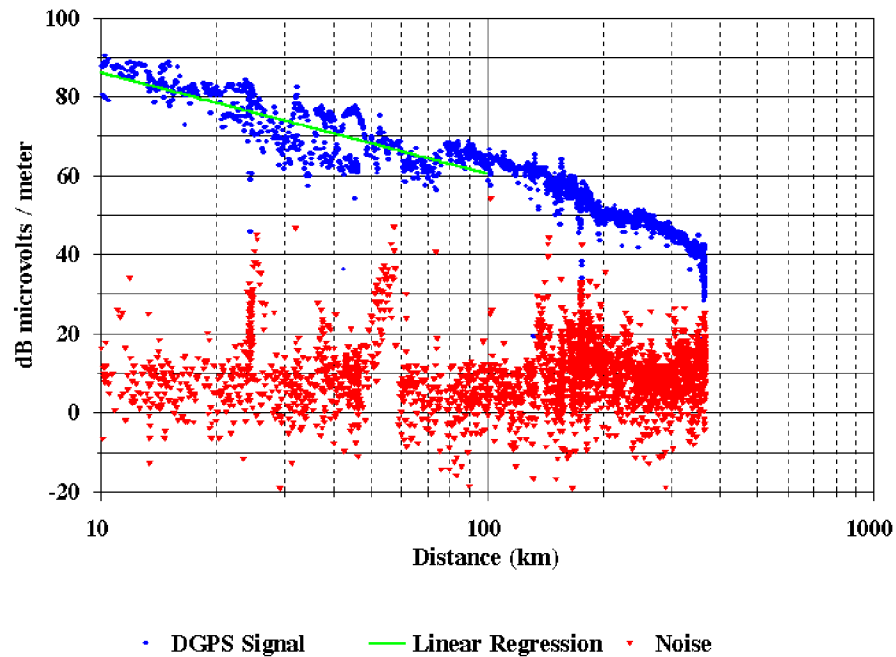

Figure 6. **Signal strength vs. distance for the Appleton GWEN site going to Spokane, Washington via Highway 395.**
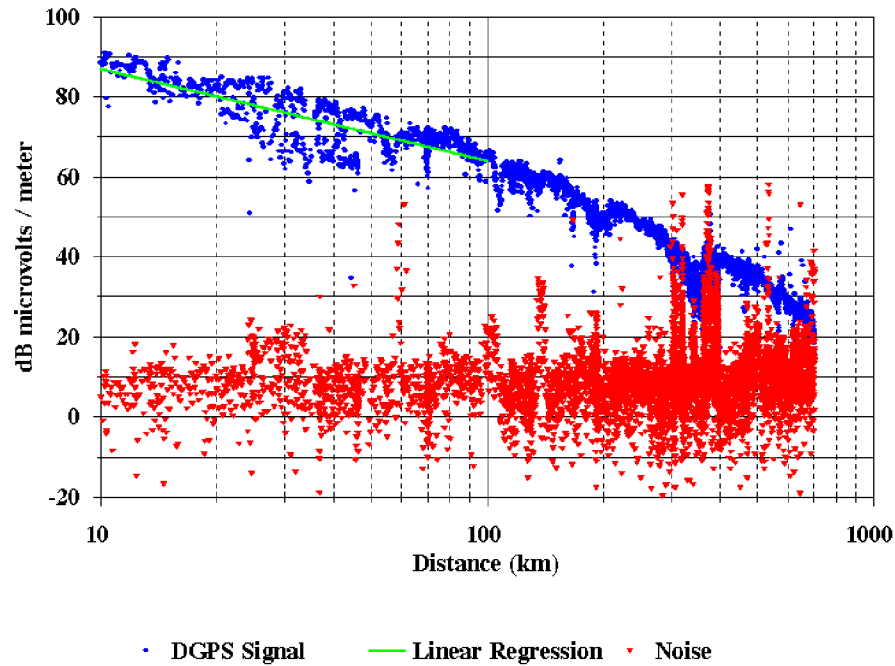
Figure 7. Signal strength vs. distance for the Appleton GWEN site going to Boise, Idaho via Highway 20.

note that the signal between the transmitter and Cascade Locks travels along the river gorge which is 2 km wide and surrounded by relatively steep hills on both sides (see Figure 11).

The route going from Boise, Idaho to Cascade Locks, Oregon shows a dip in the signal power at a distance between 200 and 400 km from the transmitter (see Figure 3). Figure 12 is a digital elevation map (DEM) showing the topography of the area. Higher elevations are represented by lighter shades of gray. High mountain peaks are white. The route from Boise, Idaho to the transmitter is shown as a thick yellow line, and the route from the transmitter to Boise is shown as a thick red line. One

Table 2. Field Strength at 10 km and Slope for Least Squares Fit

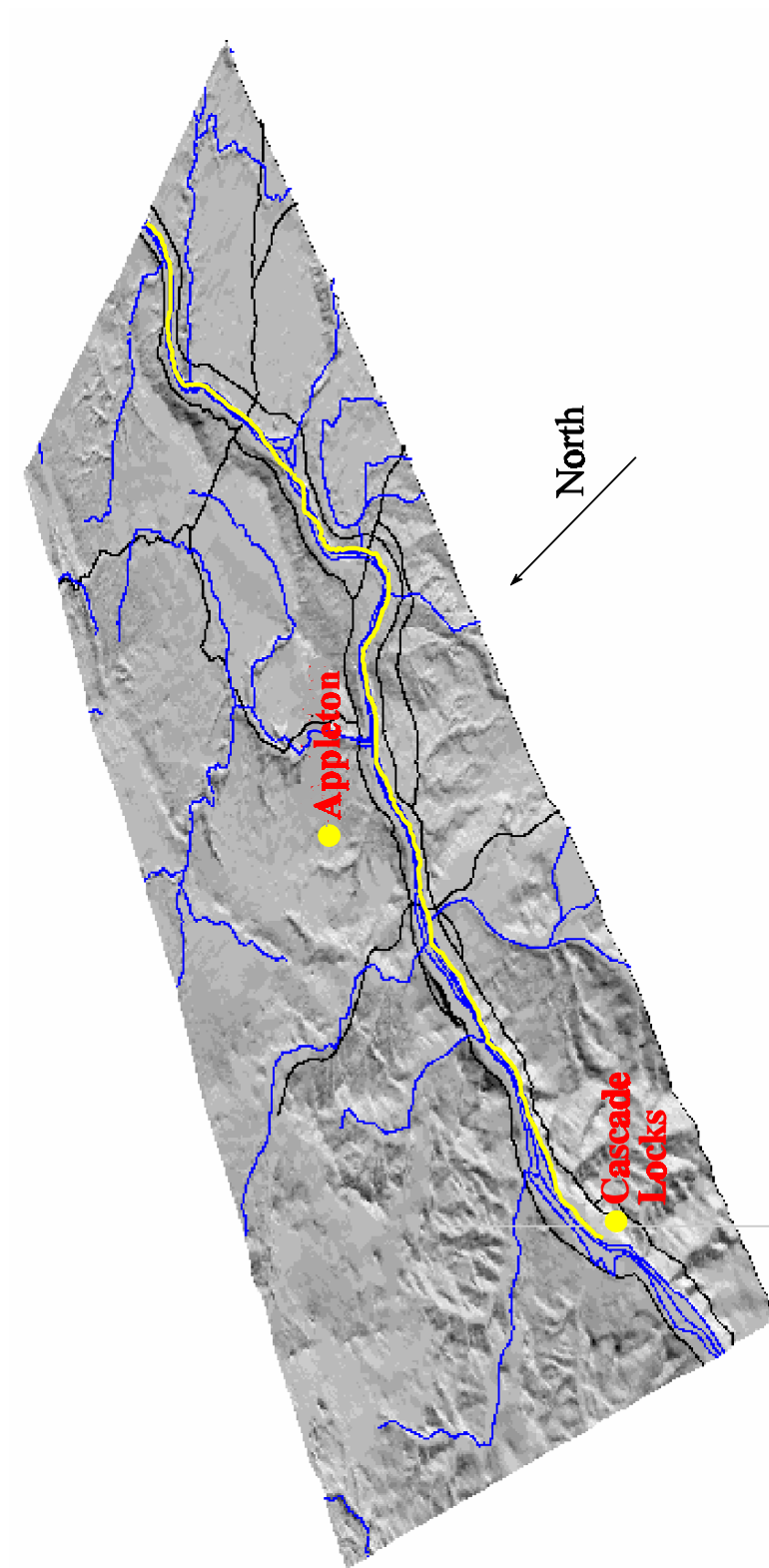| Route	Field Strength at 10 km dBµV/m	Slope (dBµV/m) / log(km)
Boise, Idaho to GWEN via Interstate 84	86.5	-24.9
GWEN to Seattle, Washington via Highway 97	88.9	-31.1
GWEN to Spokane, Washington via Highway 395	86.2	-25.6
GWEN to Boise, Idaho via Highway 20	86.9	-23.0

Figure 8. Topography of routes 45 km east and west of the Appleton GWEN site (routes shown in yellow).

North
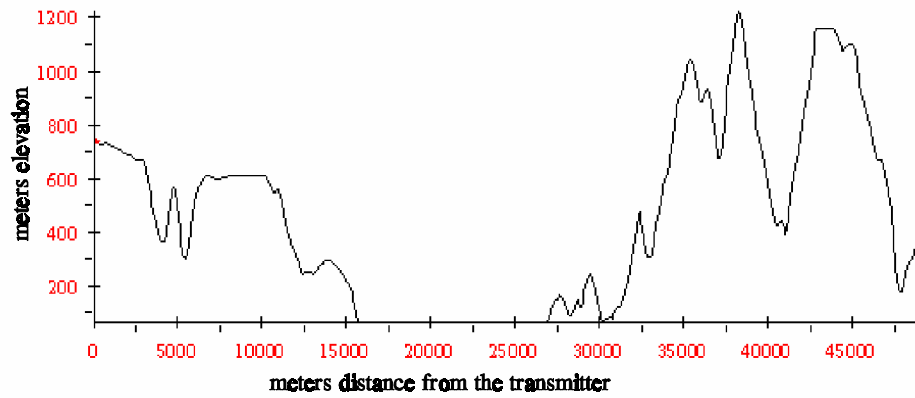
Appleton

Cascade
Locks

Figure 9. Terrain profile from the transmitter west 45 km to Cascade Locks, Oregon.
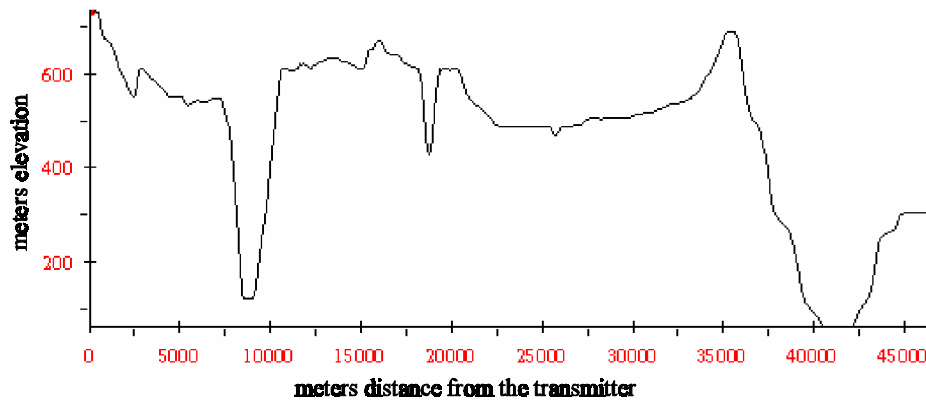

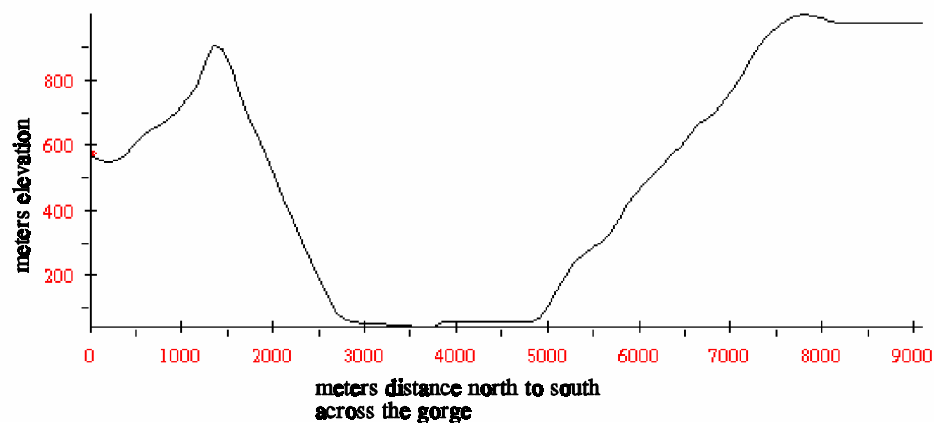**Figure 10.   Terrain profile from the transmitter east 45 km to Interstate 84.**

Figure 11.   Terrain profile from north to south across the Columbia River Gorge approximately 32 km east of the transmitter.
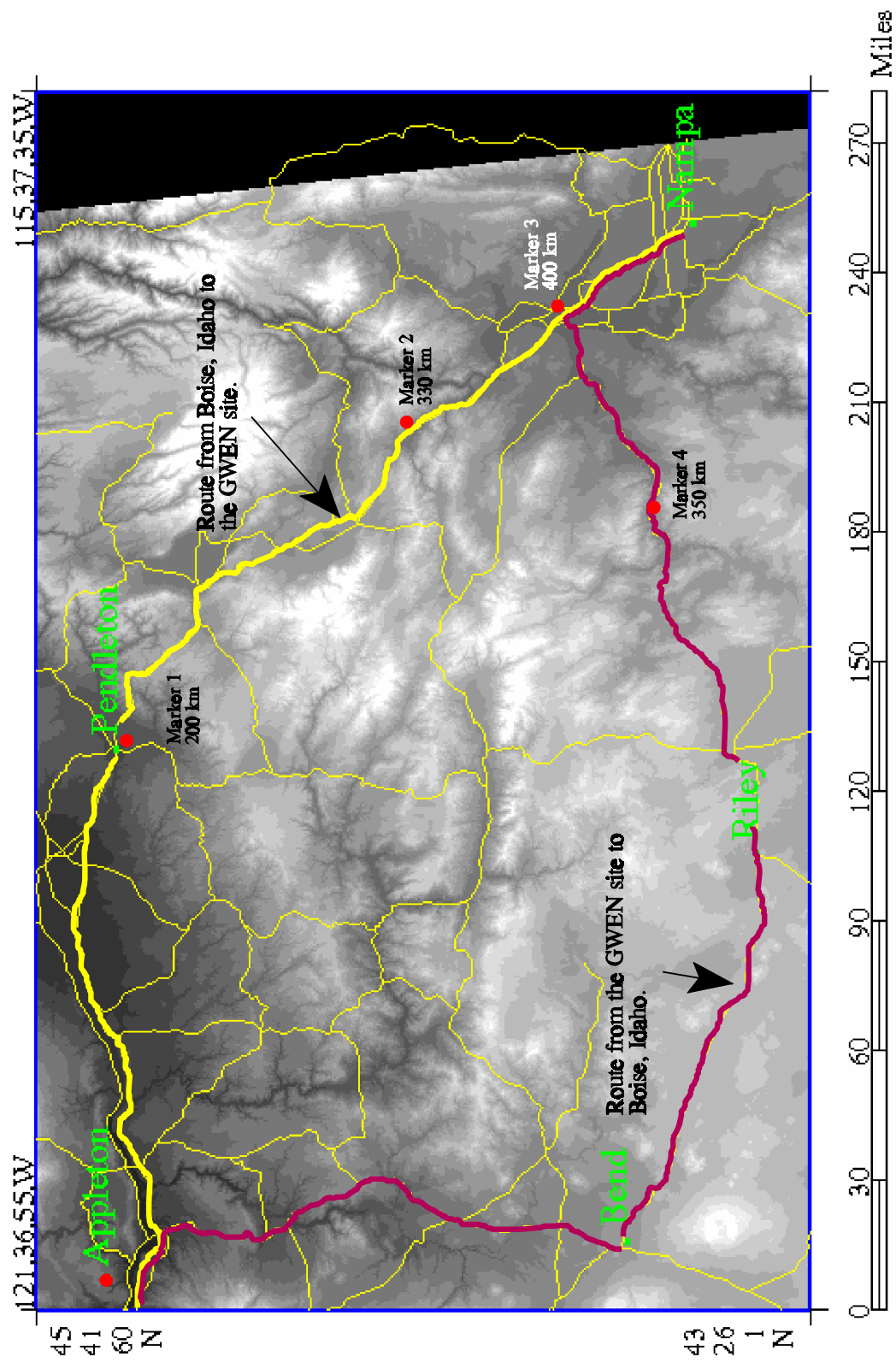
11

Figure 12. Topography for both routes between Boise, Idaho and the Appleton GWEN site, (yellow) route between Boise, Idaho and the GWEN transmitter and Burley, Idaho.

can see that when traveling between 400 km and 200 km from the transmitter along Highway 84 (marker 3 and marker 1, respectively) the signal path is obstructed by a range of mountains in the Wallowa Whitman National Forest west of the interstate. The greatest dip in the signal power occurs at 330 km from the transmitter on Interstate 84 (marker 2) where the highest point in the mountain range (Rock Creek Butte - 2773 m (9097 ft)) is in direct line with the transmitter. Two areas of significant noise elevation can be seen at approximately 120 and 320 km from the transmitter.

Traveling east to Boise, Idaho along Highways 197 and 20, one can see a different scenario. The signal power (Figure 7) shows a more gradual roll off with distances extending to 700 km from the transmitter. There is, however, a sharp dip at 350 km which then rises shortly thereafter. Figure 12 shows the terrain along this route to be flatter with less prominent obstructions. A smaller mountain range in the Malheur National Forest, lies approximately 80 km north of Highway 20. Within this mountain range is an isolated peak (Strawberry Mountain - 2757 m (9044 ft)) which is in direct line between the transmitter and marker 4 (coinciding with a distance of 350 km from the Appleton site and the dip in signal power noted above).

Data collected along the route to Bellingham, Washington show a small dip in the signal power at 63 km and a large dip between 140 km and 200 km (see Figure 4). Figure 13 shows the topography of the area with the route marked by a thick yellow line. Approaching marker 1, 63 km from the transmitter, the measurement vehicle passed over a mountain ridge and then dipped into a valley. Between marker 2 (140 km from the transmitter) and marker 3 (200 km from the transmitter) the measurement vehicle traveled over a mountain pass with the Cascade Mountains located between the receiver and the transmitter. At 200 km, when the measurement vehicle was lined up with two large mountain peaks (Mt. Rainer - 4392 m (14410 ft) and Mt. Adams - 3751 m (12307 ft)) and the transmitter, the greatest dip in the signal power occurs. It is interesting to note, however, that as the measurement vehicle continued north to Bellingham, Washington, the signal power showed a sharp rise and then a gradual roll off, notwithstanding the fact that Mt. Rainer and Mt. Adams continued to lie directly in the path.

Signal power on the route between the transmitter and Medford, Oregon (see Figure 5) shows an initial dip followed by a marked rise and then a gradual roll off. Topography of the area is shown in Figure 14 with the route marked by a thick red line. The initial dip in signal power coincides with the route along the Columbia River Gorge between Cascade Locks and the entrance to the gorge, 90 km west of the transmitter. Of the five routes, the one to Medford, Oregon shows the greatest overall attenuation over the entire distance. From Portland, Oregon to Medford, regions of the Cascade Mountains always lie between the transmitter and the receiver. Many of the mountains in this area are between 3048 and 3353 m (10,000 and 11,000 ft) high. One can also see that at Portland, located 100 km from the transmitter, the noise power was as much as 60 dB higher than the average. Measurement notes also describe power lines paralleling Interstate 5 for most of the distance between Portland and Salem, Oregon.

As can be seen in Figure 6, the signal power between the transmitter and Spokane, Washington is relatively linear without any significant areas of attenuation. Figure 15 shows the topography for the area, which is very flat with few if any remarkable geological landmarks. A few areas of elevated noise can be seen.
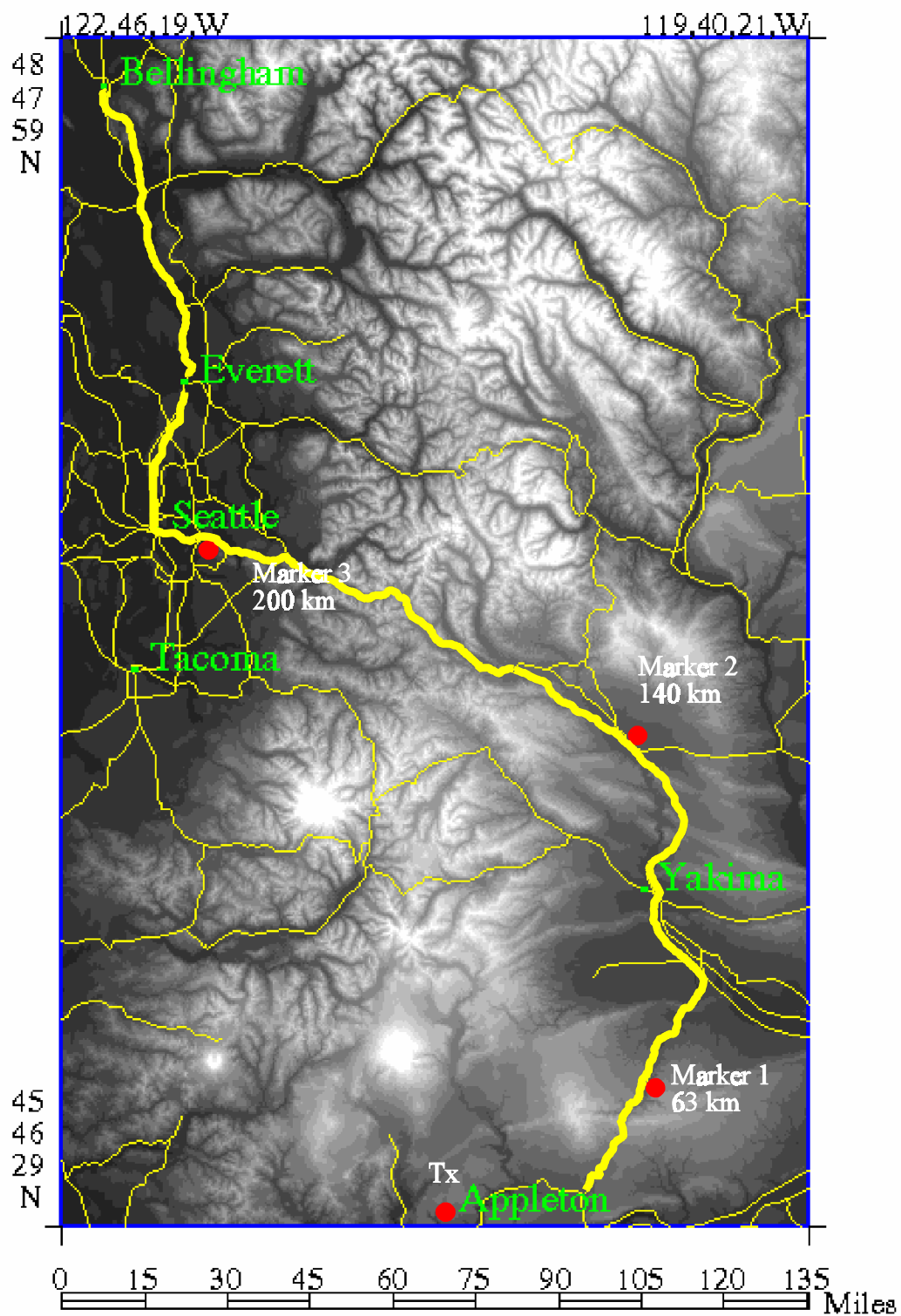
Figure 13. Topography for the route (yellow line) between the Appleton GWEN site and Bellingham, Washington.
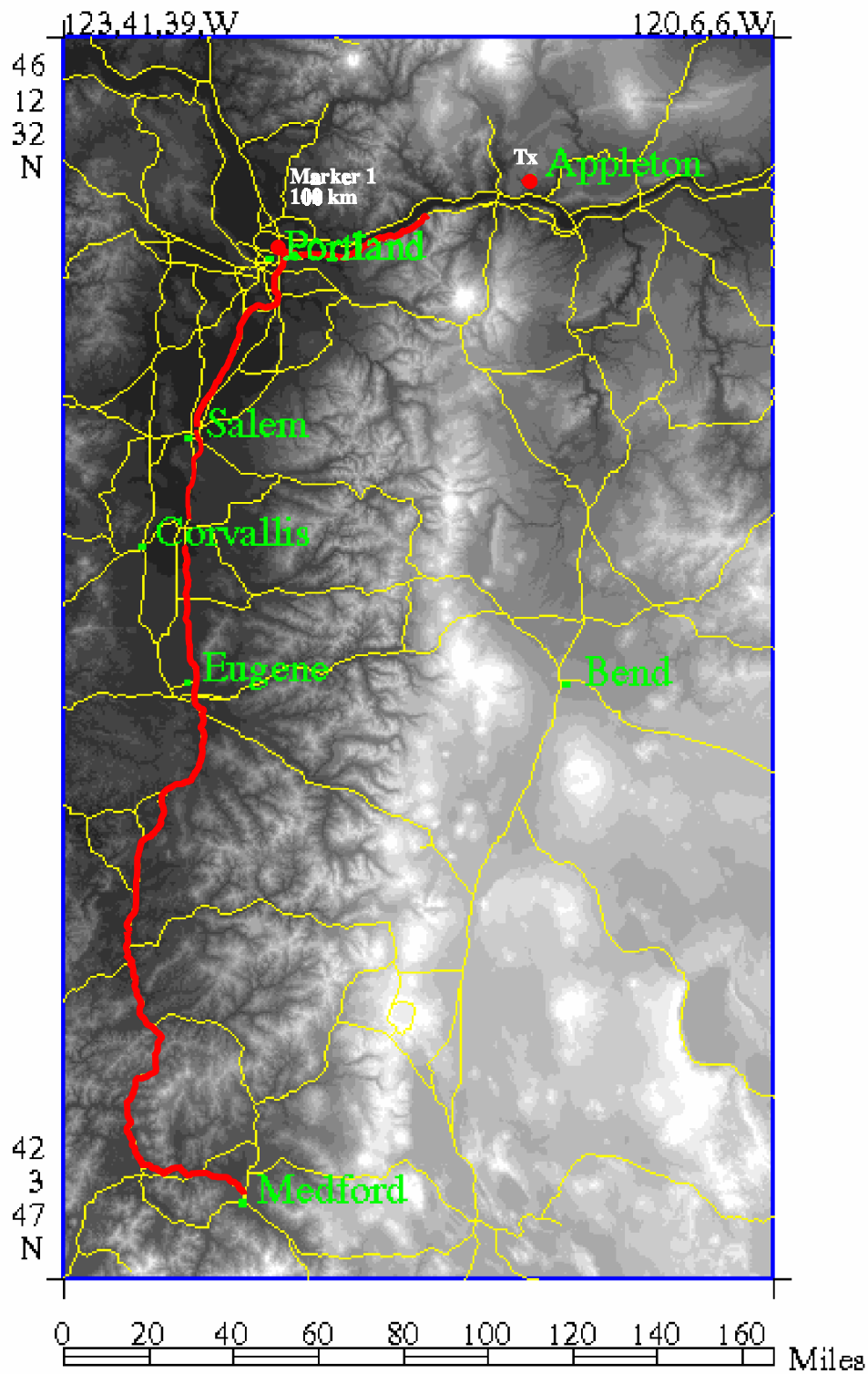
Figure 14. **Topography for the route (red line) between the Appleton GWEN site and Medford, Oregon.**